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Fermilab Proton Driver II Study

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Fermilab's Need for a New Booster



- **Planned experiments will require higher beam intensities:**
 - Higher luminosity in Tevatron.
 - Fixed target neutrino studies at the main injector and booster.
 - Possible studies involving Kaons at the main injector.
- **Present booster is the bottleneck.**
 - Can get at most 5×10^{12} protons per pulse.
 - Would like at least 2.5×10^{13} protons per pulse.
- **Upgrade of present booster a bad option.**
 - Present tunnel too shallow for necessary shielding.
 - Present tunnel (nearly circular) would limit shape of replacement.
 - HEP downtime would be unacceptable.
 - Cost of retrofitting estimated to be comparable to new booster.
 - Reuse of old magnets and rf would be constraining.
- **Propose a new and improved booster ring. Written reports due in April.**

Options for a New Booster



- **Main specification:**
 - 3.0×10^{14} protons/sec at 8 GeV
- **Two options identified.**
 - 8 GeV Superconducting Linac.
 - 8 GeV Synchrotron.
- I am participating in study of the 8 GeV synchrotron option for evaluation of space charge effects.
- <http://www-bd.fnal.gov/pdriver/8GEV/>

Synchrotron Option: Preliminary Parameter List



Proton Driver Study II: Preliminary Parameter List

(Revised, January 30, 2002)

8 GeV Proton Synchrotron

Circumference (m)	474.2
Injection kinetic energy (MeV)	600
Extraction kinetic energy (GeV)	8
Protons per cycle	2.5×10^{13}
Repetition rate (Hz)	15
Protons per second	3.75×10^{14}
Average beam current (i A)	60
Target beam power (MW)	0.48
RF frequency (MHz)	53
Number of bunches	84
Protons per bunch	3×10^{11}
Peak dipole field (T)	1.5
Good field region	4 in \times 6 in
Dispersion in the straight sections	0
Transition γ_t	$\gg 9.5$
Revolution time at injection, extraction (μ s)	2.0, 1.6
Linac injection current (mA)	50
Injection time (μ s)	90
Injection turns	45
Laslett tune shift at injection	0.25
Normalized transverse emittance (mm-mrad)	
Injection beam (95%)	3π
Circulating beam (100%)	40π
Longitudinal emittance (95%, eV-s)	
Injection beam	0.1
Circulating beam	0.2
Extraction bunch length σ_t (rms, ns)	1
Momentum acceptance	$\pm 1\%$
Dynamic aperture	$> 80 \pi$

Two Ring Options Considered. Racetrack Selected - More Useable Free Space.



Lattice Comparison

(February 28, 2002)

	REES_NEW	RITSON_NEW
Shape	racetrack	triangle
"Free" space	1.12 m × 40 3.46 m × 20 7.96 m × 14	0.84 m × 48 6.88 m × 12 6.88 m × 12
Sextupoles	20 HS, 20 VS	12 HS, 12 VS
Correctors in arc	2 per 3 QF, 2 per 3 QD	1 per 3 QF, 1 per 3 QD
RF	= 21	= 15
Extraction	yes (h or v)	yes (h or v)
Injection	yes	yes
Collimation	in the arc	in the arc or LS
DA	250 π	350 π
Δv vs. $\Delta p/p$	< 0.016 at $\pm 1\%$	< 0.005 at $\pm 1\%$
$\Delta \beta$ vs. $\Delta p/p$	< 2 m at $\pm 1\%$	< 0.4 m at $\pm 1\%$
ΔD vs. $\Delta p/p$	< 0.7 m at $\pm 1\%$	< 0.14 m at $\pm 1\%$
Δx_t vs. $\Delta p/p$	< 1.3 at $\pm 1\%$	< 0.4 at $\pm 1\%$
Δv vs. ampl.	0.205 0.062 0.062 0.347	0.183 -0.423 -0.423 0.332
Space charge	$\Delta v = 0.15$ at injection	$\Delta v = 0.15$ at injection

Space Charge Study: Injection.

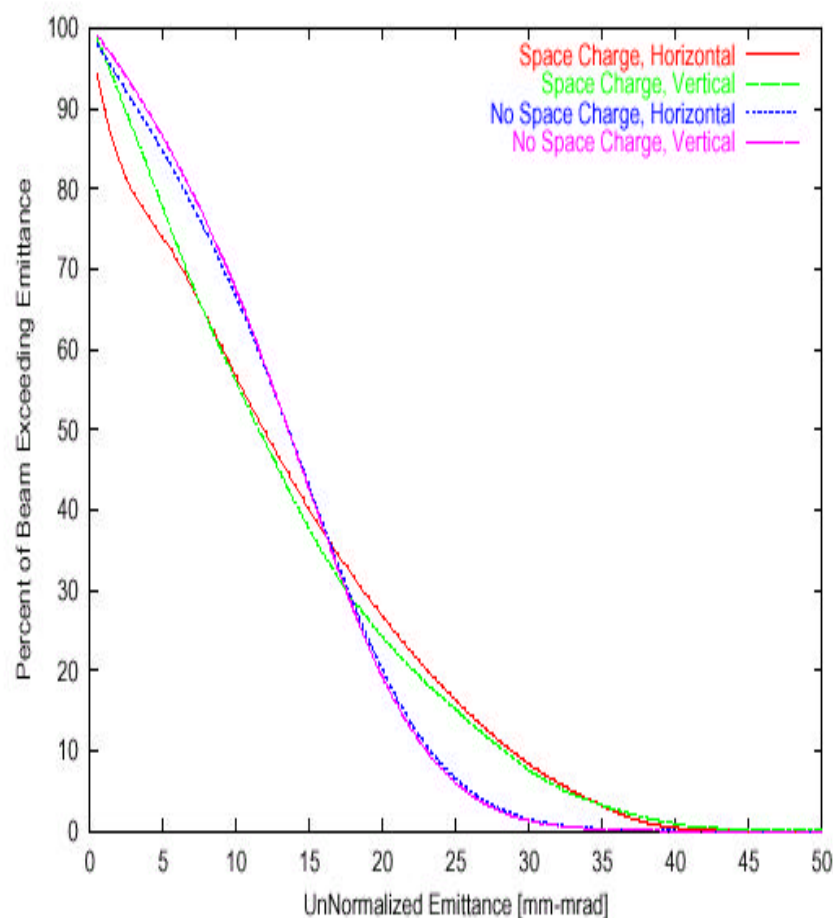


- Inject 2.52×10^{13} protons into ring over 45 turns.
 - Strip foil injection of H^- coasting beam (ignore linac bunch structure).
 - $E_{\text{kin}} = 600 \text{ MeV}$.
 - $\Delta E = \pm 500 \text{ keV}$.
 - Normalized linac emittance = 3-pi mm-mrad.
 - Paint to ring transverse emittance of 40-pi mm-mrad.
 - Bunching by adiabatic capture after injection. Ignore small rf during injection.
- Observe any emittance growth due to space charge during injection.
- Results dependent on fractional tunes

Emittance Growth is Sensitive to Tune More Than Lattice Type



Racetrack, $Q_x = 11.73$, $Q_y = 7.30$



Triangle: $Q_x = 12.14$, $Q_y = 12.36$

